EFFECTS OF THE KIMBERLY-CLARK TISSUE MILL (HUNTSVILLE) ON WATER QUALITY OF THE EAST RIVER

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Ministry
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AN INVESTIGATION OF THE EFFECTS OF THE KIMBERLY-CLARK TISSUE MILL (HUNTSVILLE) ON WATER QUALITY OF THE EAST RIVER

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SUMMARY AND CONCLUSIONS

The effluent from the new Kimberly-Clark Tissue Mill at Huntsville was found to be of high quality. Investigation of the physical, chemical, bacteriological and biological characteristics of the Lower East River revealed that the Mill is not altering the quality of the downstream waters.

A routine water quality monitoring program on the Lower East River should be continued by Kimberly-Clark of Canada Limited and will be corroborated by periodic surveys to be carried out by the Ministry of the Environment.

INTRODUCTION

In 1969, Kimberly-Clark of Canada Limited received government permission to construct a tissue mill on the East River just north of Huntsville. The 23-million-dollar plant, constructed during 1970, was designed primarily to produce tissues for household and commercial use. The plant is the company's largest tissue-making facility in Canada (100 tons per day) and contains a modern two-million-dollar waste-treatment facility including a "save-all", clarifier, settling basin, foam skimmer and a submerged outfall.

Total water treatment and use is approximately two million gallons per day with 80 to 90% of the mill waste-water being treated and reused. Actual effluent to the East River is therefore normally less than 0.5 million gallons per day.

The East River and downstream watercourses (Vernon, Fairy and Mary Lakes, Muskoka River) support a densely-used summer resort area. It is therefore imperative that good water quality be maintained through this watershed. While the sophisticated waste-treatment facilities developed by Kimberly-Clark of Canada Limited and subsequently approved by the Ministry of the Environment were designed to satisfy this objective, the Ministry organized and undertook pre- and post- operational water quality surveys of the Lower East River to investigate whether or not the receiving waters were being affected by this new industrial-waste discharge. Pre-operational sampling for chemical, physical, bacteriological and biological parameters was initiated early in the summer of 1970. The plant started production in the spring of 1971 and comparative post-operational survey work was carried out through the summer of 1971.

SCOPE OF STUDY

Data on physical-chemical characteristics of the East River were collected over two 72-hour periods. During June 8-11, 1970, two locations were sampled (E1 and E5, see Figure 1) twice. During July 20-23, 1971, five locations were sampled (E1 to E5), a total of five times. Samples of Kimberly-Clark's final effluent were collected five times during the July 20-23 survey.

Physical parameters included temperature, turbidity, color and suspended solids. Chemical parameters included a wide range of tests which are outlined in Appendix I.

Bacteriological sampling was carried out during three sampling periods in 1970, and three in 1971. The 6 sampling locations (B1 to B6) are illustrated in Figure 1. During the three 1970 visits, each station was sampled three times in May, six times in July and four times in October. In 1971, the same locations were sampled five times in May, five times in July and three times in November. Water samples were analyzed for total coliforms, fecal coliforms, fecal streptococcus, total plate counts, cellulose decomposers, sulfate reducers and chemoautotrophic sulfur oxidizers. Sediment samples were analyzed for cellulose decomposers, sulfate reducers and chemoautotrophic sulfur oxidizers.

The biological survey was limited to an investigation of the bottom macroinvertebrate community. Five locations were sampled (K1 - K5 , see Figure 1) in June, July and August of both 1970 and 1971. Invertebrates were collected using both the "qualitative" sampling technique as well as using "artificial substrates".

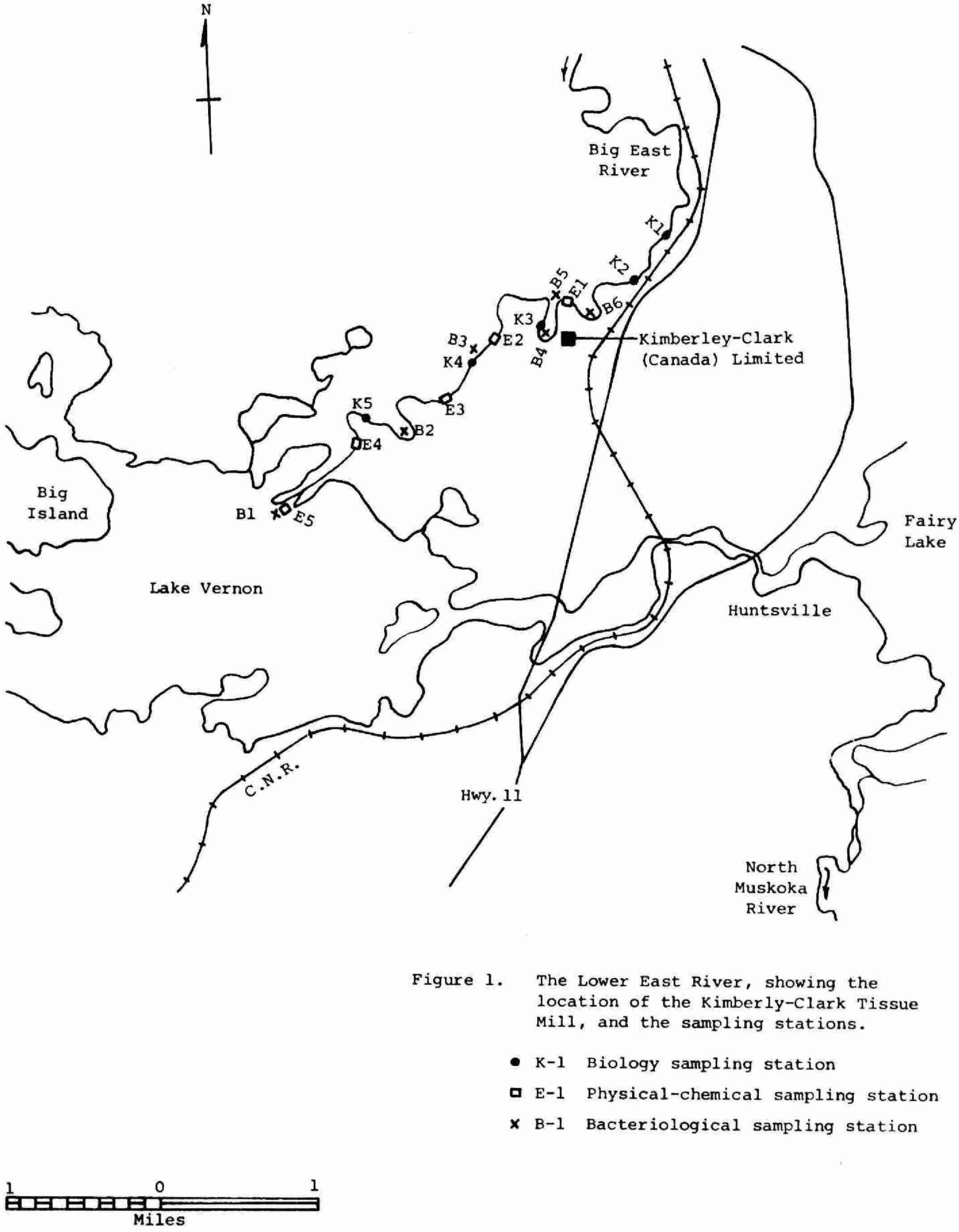

Figure 1. The Lower East River, showing the location of the Kimberly-Clark Tissue Mill, and the sampling stations.

● K-1 Biology sampling station

□ E-1 Physical-chemical sampling station

× B-1 Bacteriological sampling station

METHODS

Physical

Surface water temperatures were measured using a standard mercury hand thermometer. Water samples for turbidity, color and suspended solids were collected from just below the surface and were analyzed at the Ministry's laboratory in Rexdale using standard procedures (Standard Methods, 13th edition) or modifications of these procedures that have been adopted by the Ministry.

Chemical

Dissolved oxygen in the surface water was measured in the field using a YSI-54 meter which was calibrated daily against the oxide modification of the wet Winkler method. Samples for the other chemical analyses listed in Appendix I were collected just below the surface and were analyzed at the Rexdale laboratory. Again, either standard methods, or modifications of these methods adopted by the Ministry, were used.

Bacteriological

Surface water samples were collected in 250-ml sterile polycarbonate bottles and sediment samples were placed in sterile 4-oz. jars, collected by means of an Ekman dredge. The samples were stored on ice and delivered to the mobile laboratory within 4 hours. Analyses were done on surface samples for total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) using the membrane filtration technique (MF) described in Standard Methods (13th Edition) (1) with one exception: the media used to determine FC was MacConkey membrane broth (Oxoid). Total plate count organisms (TPC) were enumerated according to Standard Method techniques.

Sulphate reducing organisms (Desulfovibrio sp.) were enumerated in both the water and sediment using Thompson's (2) modification of the submerged membrane plate method described by Tsuneishi and Goetz (3). The

sulfate reducers were incubated at room temperature for ten days in Brewer jars using the H_2-CO_2 "Gas Pak" system (Baltimore Biol. Labs).

A three-tube, most probable number (MPN) dilution technique was used to enumerate the chemoautotrophic sulfur-oxidizing bacteria in the water and sediment. The sulfate broth media described by Postgate (4) was used for growth of Thiobacillus thiooxidans and Thiobacillus thioparus. All tubes were incubated in the dark at room temperature for 4 weeks. Determination of the growth of the Thiobacillus sp. was based on a decrease in pH using pH indicator paper (pH range 2 to 10).

Cellulose-decomposing organisms were enumerated in both surface water and sediment using a three-tube MPN method. The media used was a mineral salt solution supplemented with 0.1% yeast extract and a strip of filter paper as described by Han and Srinivasan (5). The tubes were incubated at room temperature and the filter paper checked weekly for three weeks for mottled or yellow brown areas indicating cellulytic activity. No attempt was made to speciate these organisms found.

Biological

The artificial substrates used to provide attachment surfaces for the macroinvertebrates consisted of 6" x 8" x 8" wire mesh baskets filled with 2 1/2" crushed limestone. At each station, one substrate was placed in the water by a diver (using snorkelling gear) in May. The substrates were positioned on submerged logs or on hard sediments and tied to a suitable underwater object (e.g. submerged log).

At monthly intervals (i.e. June, July, August) divers were used to recover the substrates. The divers

would carefully roll the substrates into a large pail which contained a brass screen in the bottom (24 meshes per inch, 0.65 mm. aperture). The pail screen and substrates were then carried to the surface in such a way that animals dislodged from the substrate would be caught in the pail screen. Invertebrates were extracted from the substrate sampler by brushing each stone with a tooth brush. After all the rocks had been cleaned, the basket was refilled and placed back in the water.

Qualitative samples which were collected at each station in June, were obtained using a variety of collecting techniques. Shallow-water areas along the shorelines were sampled by picking organisms from rocks and twigs, sifting sediment, analyzing detritus from undercut banks, etc. Efforts were made to sample a large variety of habitats. A sampling time of one hour (3 collectors) was employed at each station in order to obtain comparable data between sampling locations.

All organisms collected were preserved in 70-90% ethanol and returned to the Rexdale laboratory for enumeration and identification.

DISCUSSION OF RESULTS

Physical-Chemical

Average physical-chemical results are illustrated in Appendix I.

Parameters measured indicated no apparent change in water quality of the East River between 1970 and 1971. Also, a comparison of the post-operational data upstream (E1) from the Kimberly-Clark Tissue Mill, with that col-

lected downstream (E2 to E5) revealed that the effluent from the Tissue Mill was not altering water quality of the river.

Analyses of the Kimberly-Clark discharge showed that the effluent was of satisfactory quality (see Appendix I). Several ions, including calcium, chloride, sodium, potassium and magnesium were found to be more concentrated in the effluent than they were in the East River. Nitrogen was also slightly higher in the effluent. However, concentrations of these elements were acceptable and the less specific parameters of conductivity, hardness and total solids illustrate that the cumulative effect of low-toxicity ions in the discharge should not present problems.

It is also of interest to note that many chacteristics of the effluent water - dissolved oxygen, temperature, BOD_5, COD, sulfate, phosphorus, turbidity and pH, were very similar to the characteristics of the East River itself. Two parameters, namely iron and color, were less concentrated in the Kimberly-Clark effluent than they were in the river.

It should be pointed out that analyses of the mill effluent and the above comments were based on an average of only five samples which may provide only a rough representation of the long-term average quality characteristics. However, the information revealed an effluent of sufficiently high quality that minor alterations in the effluent characteristics should not present problems.

Bacteriological

Data from the six surveys were subjected to a

statistical comparison using a multiple-t test. The geometric mean for each individual bacteriological parameter for each station has been compared with all other stations for both years and this statistical data is retained in permanent file by the Laboratory Branch. This does not include a comparison between the spring surveys and the summer or fall surveys since there is not sufficient data to establish seasonal trends at this time.

A. Sulfate reducers (Desulfovibrio sp.)

In the May surveys, there was no significant change in the concentration of sulfate reducing organisms in the water, either over the length of the study area or from 1970 to 1971 (Table 1). The only exception was station B-6 in 1971 with the highest concentration of sulfate reducers (30/100 ml) and station B-3 in 1970 with the lowest number of sulfate reducers (4/100 ml).

Generally, in the July surveys, there were no significant upstream to downstream changes in concentrations of sulfate reducers in either 1970 or 1971, nor were there significant differences between the data from the two years (Table 1); the exceptions were station B-3 in 1971 with a higher mean of 60/100 ml and station B-5 in 1970 with the mean of 6/100 ml. Generally there was an increase in the number of Desulfovibrio sp. from May to July, especially in 1971. This increase probably reflected the increase in temperature.

During the October 1970 and November 1971 surveys, there was no significant difference between the stations (Table 1) except for station B-5 in 1971 which was quite high (15/100 ml) and station B-1 in 1970 and 1971 which had the lowest means of 3/100 ml and 2/100 ml respectively.

TABLE 1. Concentrations of four types of bacteria in surface water at the six sampling locations. Numbers reflect geometric mean values per 100 mls.

	Survey Dates	B-1	B-2	B-3	B-4	B-5	B-6
Sulphate Reducers	May 26-29, 1970	10	7	4	5	8	10
	May 7-11, 1971	17	6	10	5	3	30
	July 7-16, 1970	8	9	35	17	6	20
	July 20-28, 1971	22	28	60	48	33	26
	Oct. 2-5, 1970	3	6	7	5	17	10
	Nov. 3-6, 1971	2	12	6	4	15	6
Thiobacillus thiooxidans	May 26-29, 1970	3	4	6	4	5	3
	May 7-11, 1971	3	4	4	6	7	6
	July 7-16, 1970	10	6	11	10	7	6
	July 20-28, 1971	4	3	7	5	7	7
	Oct. 2-5, 1970	4	4	14	6	4	4
	Nov. 3-6, 1971	8	3	3	3	7	3
Thiobacillus thioparus	May 26-29, 1970	5	6	8	5	6	5
	May 7-11, 1971	27	19	25	22	30	25
	July 7-16, 1970	7	13	10	4	9	7
	July 20-28, 1971	6	5	8	9	4	6
	Oct. 2-5, 1970	4	16	10	16	7	11
	Nov. 3-6, 1971	7	6	9	6	6	6
Cellulose Decomposers	May 26-29, 1970	3	3	6	5	9	6
	May 7-11, 1971	5	14	11	16	7	11
	July 7-16, 1970	11	5	16	9	9	26
	July 20-28, 1971	3	4	8	11	3	8
	Oct. 2-5, 1970	6	11	26	18	24	19
	Nov. 3-6, 1971	8	22	3	5	8	8

There were no sulfate reducers isolated from the sediment (<100/gm) in 1970 and by decreasing the dilution in 1971 there were still <10/gm. The lack of success in isolating Desulfovibrio sp. from the sediments is probably largely a function of the loose sandy bottom which was strongly washed and stripped by the strong current. It was interesting to note that the sulfate reducers were prevalent and appeared to be active in the surface water which contained high levels of dissolved oxygen. Yet these organisms which are generally associated with anaerobic conditions, were not detected in the sediments (i.e. 100 or 10/gm). This finding supports the work of Menon & Mercier on Lake Erie (6). These authors found a good correlation between dissolved oxygen and quantity of Desulfovibrio and suggest that, contrary to popular belief, sulfate reducing organisms do appear to tolerate oxygen, in fact, Desulfovibrio may be facultatively anaerobic. However, these authors had not been able to isolate Desulfovibrio sp. where the dissolved oxygen exceeded 8.2 mg/l. The mean dissolved oxygen measured on the East River ranged from 7.2 mg/l to 8.2 mg/l (Appendix I).

The data imply that the sulfate reducers are indeed tolerant to oxygen, or there would have been a decrease in their concentration as the river flowed toward Lake Vernon, unless the sediments contained these organisms and released them at a fairly constant rate into the water. However, none were found in the sediment.

Comparison of this data with that collected in the Ottawa River (2) (excluding those areas influenced by outfalls) indicated that the East River generally had slightly higher concentrations of sulfate reducers in the surface water. The sediments were similar since populations were generally below the measurable levels.

B. Thiobacillus sp.

The Thiobacillus thiooxidans showed little significant variation in the May, July or October-November surveys along the length of the river or between 1970 and 1971 (Table 1). The stations that were significantly different were either high or low with no apparent cause.

The Thiobacillus thioparus in May 1971 were quite high with means significantly exceeding those in May 1970 as well as all means during the other four surveys. This was unusual since the temperature in May was below the optimum required for the growth of Thiobacillus sp., 20°C to 40°C (Fleirman et al (7)). Assuming that this increase was a result of a readily metabolizable sulfur input, a corresponding increase should have been apparent in the T. thiooxidans. The other surveys generally showed no significant differences between station in 1970 or 1971 (Table 1). The concentrations of T. thioparus were generally higher than the T. thiooxidans since the pH of the river water was too high to readily support the T. thiooxidan growth.

A comparison of the numbers of sulfur oxidizing bacteria in the Ottawa River (OWRC, 1970) and the number of these bacteria in the East River revealed that, generally, the Ottawa River had less than 3 (or undetectable quantities) while the East River had greater than 3 and often appreciably higher numbers of these organisms (Table 1).

C. Cellulytic bacteria

The cellulose decomposing organisms showed little significant variation either along the length of the river surveyed or between the years 1970 and 1971 (Table 1.)

Even though the optimum temperature for cellulytic bacteria was shown to be around 20^{o}C (Berg) (8), the July surveys did not have the highest levels of these organisms, instead, in 1970, the fall survey was highest. These high levels in the fall may be a reflection of the large amount of decaying plant material that was present in the river in October. There is no explanation for the relatively high levels of these organisms in the spring of 1971.

D. <u>Total Plate Count organisms (TPC)</u>

There was generally no significant difference in TPC concentrations along the river or between 1970 and 1971 except during the October 1970 survey when the TPC concentrations were approximately three times higher than in November 1971 (Table 2). Both the cellulytic organisms and total heterotrophic populations were high in October 1970 possibly as a result of the nutrient input from the decaying vegetation in the water.

E. <u>Total coliforms, Fecal coliforms and Fecal Streptococcus (TC, FC and FS)</u>

There was no significant increase or decrease in the TC, FC and FS populations as the river flowed from station B-6 to B-1 past the Kimberly-Clark mill (Table 2). The TC and FC concentrations, although below the established Ministry criteria for total body contact recreational use (OWRC, 1970 (9)), were unusually high for an undisturbed watershed and imply that sewage was gaining access to the river. The FS means during July in both 1970 and 1971 exceeded the permissible FS level, as did most stations in October and November. The FC/FS ratio (Geldreich 1968) (10) suggested that the input was largely domestic sewage in May, while the ratio during July and October implied that the contamination was largely of animal origin (Table 3).

TABLE 2. Concentrations of four types of bacteria in surface water at the six sampling locations. Numbers reflect geometric mean values per 100 mls.

	Survey Dates	B-1	B-2	B-3	B-4	B-5	B-6
Plate Count	May 26-29, 1970	19,383	23,426	16,060	23,221	26,705	24,890
	May 7-11, 1971	14,700	16,800	13,600	16,100	13,600	23,700
	July 7-16, 1970	12,234	19,137	21,507	21,405	14,177	17,703
	July 20-28, 1971	11,600	25,800	36,400	47,100	19,400	54,900
	Oct. 2-5, 1970	67,299	73,734	72,788	70,518	76,964	64,628
	Nov. 3-6, 1971	20,600	28,400	20,900	16,600	28,300	21,200
Total Coliform	May 26-29, 1970	58	69	69	77	54	63
	May 7-11, 1971	131	145	213	187	155	147
	July 7-16, 1970	123	187	189	161	129	123
	July 20-28, 1971	84	137	115	127	129	177
	Oct. 2-5, 1970	79	78	69	76	91	85
	Nov. 3-6, 1971	272	257	278	291	354	365
Fecal Coliform	May 26-29, 1970	7	10	10	15	21	11
	May 7-11, 1971	2	1	1	3	2	1
	July 7-16, 1970	41	61	61	55	61	65
	July 20-28, 1971	25	22	26	13	30	24
	Oct. 2-5, 1970	22	20	20	18	23	20
	Nov. 3-6, 1971	3	4	4	5	5	2
Fecal Strepto-coccus	May 26-29, 1970	4	4	5	4	8	4
	May 7-11, 1971	1	1	2	1	2	1
	July 7-16, 1970	34	65	92	89	39	57
	July 20-28, 1971	39	37	58	41	44	44
	Oct. 2-5, 1970	35	27	31	32	20	20
	Nov. 3-6, 1971	10	28	27	15	39	30

Table 3. Ratios of Fecal Coliforms to Fecal Streptococcus at the six sampling locations, 1970 and 1971.

	1970 FC/FS Ratio		1971 FC/FS Ratio
Stn. B-1	May	1.8	2.0
	July	1.2	.6
	Oct-Nov	.6	.3
Stn. B-2	May	2.5	1.0
	July	.9	.6
	Oct-Nov	.7	.1
Stn. B-3	May	2.0	.5
	July	.7	.4
	Oct-Nov	.6	.1
Stn.B-4	May	3.8	3.0
	July	.6	.3
	Oct-Nov	.6	.3
Stn. B-5	May	2.6	1.0
	July	1.6	.7
	Oct-Nov	1.2	.1
Stn. B-6	May	2.8	1.0
	July	1.1	.5
	Oct-Nov	1.0	.1

The FC/FS ratio which is based on many observations, revealed that sewage of human origin had a ratio of 4.0 or greater, while stormwater runoff and animal sewage had a ratio of 0.7 or less.

Biological

Appendix II illustrates the types and numbers of macroinvertebrates that were found at the five sampling locations during 1970 and 1971.

Although the organisms were collected at various times and using two methods as outlined in the Methodology Section, a "break-down" of invertebrates obtained from each sample is not provided. Appendix II, as well as Figures 2 and 3, simply provide the data on the total numbers and types of organisms collected during each year at each sampling location. Details of the invertebrates collected from each sample are stored on file cards at the Ministry of Environment (Water Quality Branch).

In general, the East River was found to support a very large variety of macroinvertebrates. Figure 2 illustrates that between 16 and 33 taxa were found per station per year, even though most of the organisms were identified only down to the family level. This large diversity within the community, along with the moderate density of animals and the good balance between taxa, illustrates clean-water conditions.

In order to evaluate the effects of the Kimberly-Clark discharge on the biology of the East River, several comparisons are made. These comparisons deal with the presence or absence or changes in community structure and density between 1970 and 1971, as well as the presence or

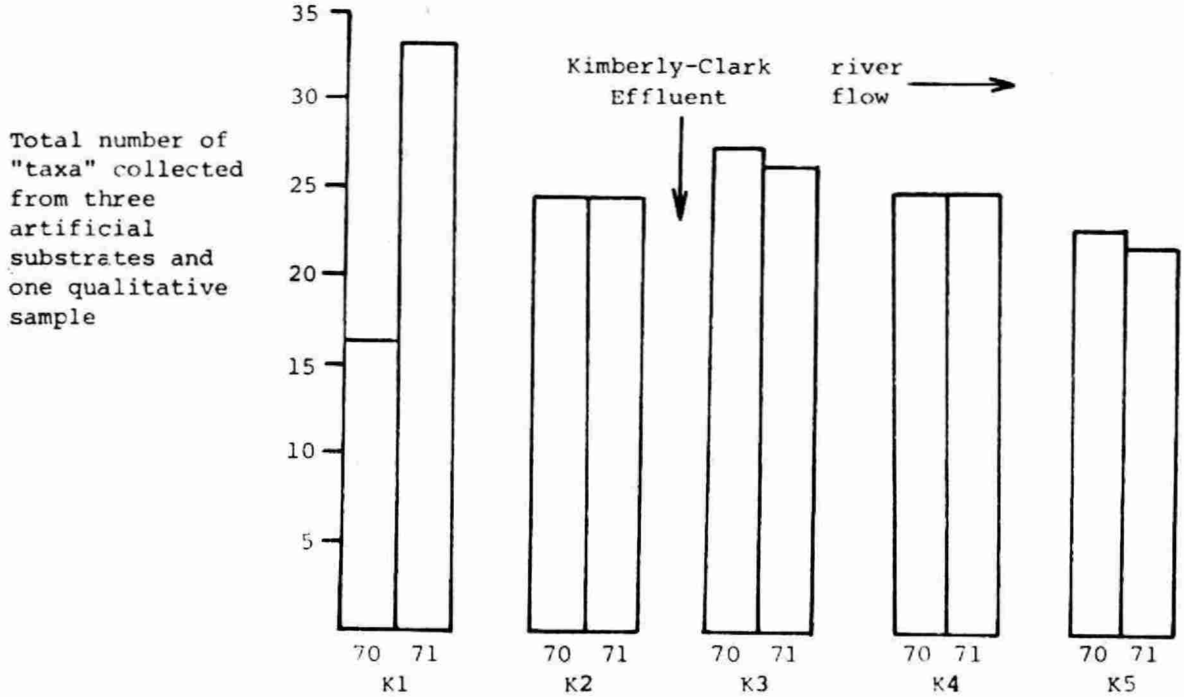

Figure 2: Total number of taxa collected at each sampling location during 1970 and 1971
A taxon refers normally to family (see Appendix II)

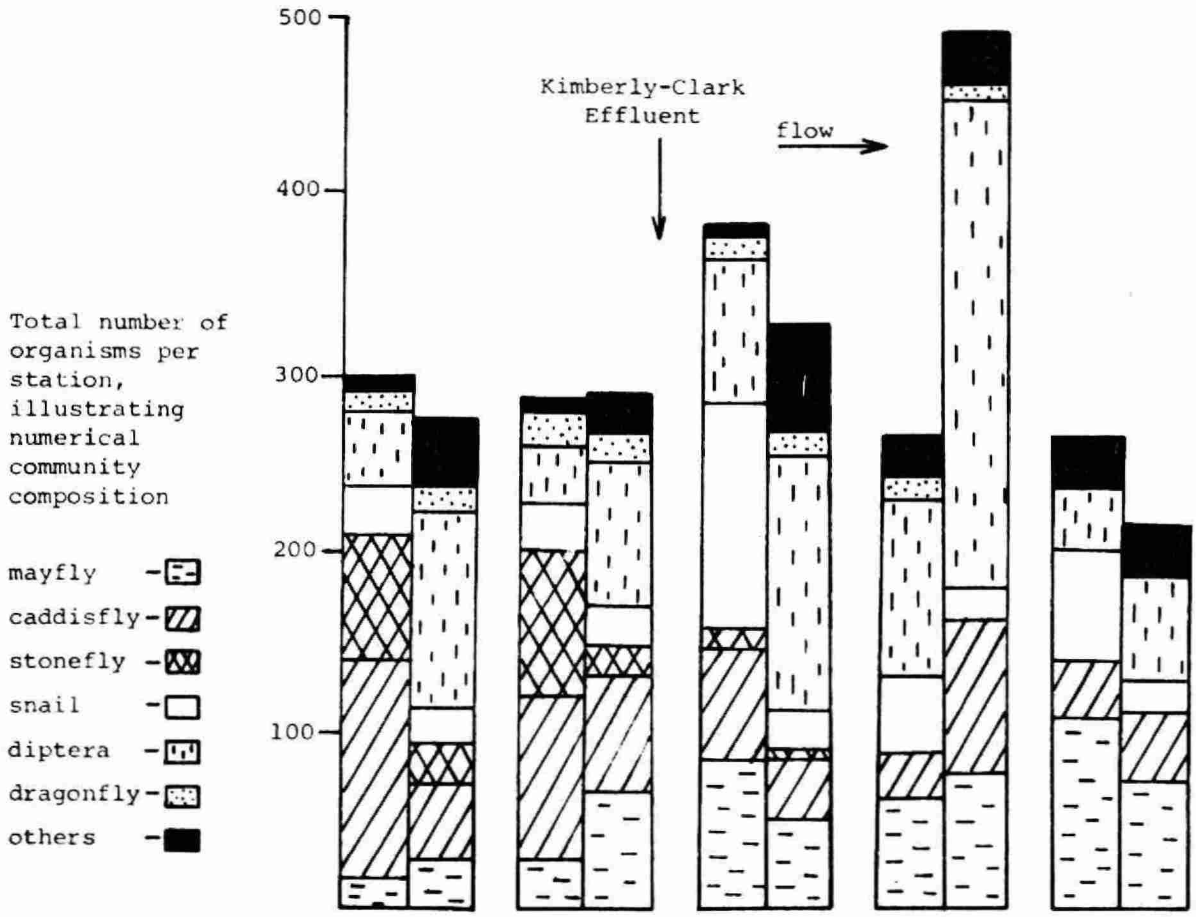

Figure 3: Total number of invertebrates found at each sampling location during 1970 and 1971.
Numerical community composition is also illustrated.

absence of changes between the upstream data (K1 and K2) and downstream data (K3 - K5) during 1972.

The variety of taxa (i.e. number of taxa) at each station, as well as the types of organisms found and the balance between groups, is probably the most sensitive indicator of biological health. Figures 2 and 3 illustrate community diversity, population densities and community composition. The considerable difference in the number of taxa collected in 1970 and 1971 at K1 is unexplainable and may or may not relate to changes in water quality between the two years. However, there was no appreciable change in pre-operational and post-operational numbers of taxa from K2 and K5. In fact, there was a surprisingly high similarity between the two years in both diversity (Figure 2) and community "make-up" (Figure 3).

Figure 3 also illustrates the total numbers of organisms collected per station per year. While the numbers from station to station and from 1970 to 1971 at any one station show considerable differences, the differences are no greater than could be expected from the unavoidable difficulty in duplicating the sampling efficiency and sampling points. Population densities at each station can therefore be regarded as being similar between 1970 and 1971.

Another method of comparing benthic communities is through the use of mathematical indices. Table 4 illustrates two indices, the Coefficient of Community Similarity and Margalef's Diversity Index. While the Coefficient of Community Similarity is lower than would be expected at all the stations, the index does indicate that the community similarity between 1970 and 1971 was no different downstream from Kimberly-Clark than it was upstream. The abnormally low coefficient at K1 is a result of the unexplainable difference

TABLE 4: Comparisons of benthic communities on the East River (1970 and 1971) using two mathematical indices.

A) Coefficient of Community Similarity (C)

$$C = \frac{c}{a+b-c} \times 100$$

where a = # taxa in 1st sample (1970 sample)
b = " " " 2nd " (1971 sample)
c = " " common to both samples

C (between 1970 and 1971)	
K1	19%
K2	55
K3	61
K4	52
K5	46

B) Margalef's Diversity Index (D')

$$D' = \frac{S - 1}{\log_e N}$$

where S = # of taxa
N = # of organisms

	D'	
	1970	1971
K1	2.6	5.7
K2	4.1	4.1
K3	4.4	5.8
K4	4.3	3.9
K5	3.9	3.9

in variety of taxa collected in 1970 and 1971.

Margalef's Diversity Index is very useful in evaluating biological health of a watercourse. Table 4 shows that the community diversity did not change notably after the tissue mill started production.

A comparison of the 1971 bottom fauna data collected downstream from the Kimberly-Clark discharge (K3 - K5), with that collected upstream (K1 & K2), also reveal no detectible effects of the tissue mill (see Figures 2 and 3, Table 4). It is therefore concluded that the new industrial operation is having no detectible effect on the bottom fauna of the East River.

Bottom fauna is a sensitive and commonly used biological parameter and it can be assumed that an investigation of other biological components would have yielded similar results and conclusions.

FUTURE MONITORING

The techniques and parameters used by the Ministry of Environment appear to have been ample in satisfying the purpose of the study. The water quality norm of the Lower East River has now been defined and data from future monitoring can be compared to this "background" information. The bottom invertebrate community, which is very diverse and includes several pollution-sensitive groups of organisms, (e.g. stoneflies, mayflies, caddisflies) will serve as a sensitive indicator of water quality changes in the future.

Because of the heavy recreational demands on the waters in the Huntsville area, it is important that the Lower East River be monitored on an annual or bi-annual basis. It is the policy of this Ministry to require

industry to monitor their effluent quality as well as check conditions in the receiving watercourse, on a continuing basis. When Kimberly-Clark of Canada Limited was approached with this suggestion, the Company responded immediately by implementing a 1972 follow-up survey that was in accordance with the wishes of this Ministry. It is understood that similar surveys will be carried out by the Company in future years.

It is planned that the Ontario Ministry of the Environment (Water Quality Branch) will conduct water quality studies of the Lower East River at approximately five-year intervals in order to ensure the long-term maintenance of good water quality in this important recreational area.

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APPENDIX I: Physical-Chemical Data (Mean Values) collected on the East River during the 1970 and 1971 surveys.
(Note - Appendix I continued on following page)

		D.O. mg/l	Temp. ^{0}C	BOD_5 mg/l	COD mg/l	Conductivity umhos/cm	Phosphorus mg/l Tot.	Phosphorus mg/l Sol.	Nitrogen mg/l NH_3	Nitrogen mg/l Kjeld.	Nitrogen mg/l NO_2	Nitrogen mg/l NO_3	Turbidity J.T.U.	Colour Units	pH
1970	E1	7.9	20.7	0.7	<30	41	.029	.007	.04	.34	.007	.16	4	35	7.3
	E5	7.9	21.2	0.7	<30	42	.027	.023	.03	.32	.005	.13	4	32	7.1
1971	E1	8.2	18.9	1.0	<30	39	.019	.003	.02	.27	.004	.11	5	25	6.7
	E2	7.9	18.9	0.9	<30	39	.015	.003	.01	.27	.003	.12	6	25	6.8
	E3	8.2	18.9	0.7	35	39	.015	.002	<.01	.25	.003	.11	5	30	6.7
	E4	7.9	18.9	0.8	<30	39	.014	.002	<.01	.25	.003	.10	6	25	6.7
	E5	8.2	19.0	0.9	<30	38	.017	.002	.02	.24	.004	0.1	5	25	6.7
Kimberly-Clark Final Effluent		7.2	20.0	0.9	<30	197	.014	.003	.04	.44	.027	0.6	5	5	6.2

APPENDIX]: Continued

	Solids mg/l Diss.	Solids mg/l Total	Alkalinity mg/l $CaCO_3$	Hardness mg/l $CaCO_3$	Calcium mg/l	Magnesium mg/l	Sulfate mg/l	Chloride mg/l	Iron mg/l	Sodium mg/l	Potassium mg/l
1970 E1	32	37	8	22	-	-	-	2	0.43	-	-
E5	37	43	7	17	-	-	-	2	0.42	-	-
1971 E1	-	43	-	14	4	<1	9	2	0.47	1.3	.63
E2	-	38	-	14	4	<1	7	3	0.46	2	.70
E3	-	30	-	14	4	<1	5	2	0.48	1.5	.75
E4	-	27	-	14	4	<]	5	2	0.49	1.5	.60
E5	-	33	-	14	4	<1	4	2	0.50	2.5	.70
Kimberly-Clark Final Effluent	-	185	-	68	23	3	12	39	0.1	12	2.3

APPENDIX II. A summary comparison of the benthic invertebrates collected in 1970 and 1971 on the East River. Numbers refer to total organisms collected from 3 artificial substrates plus a 1-hour qualitative sample at each sampling station.

	K1		K2		K3		K4		K5	
	70	71	70	71	70	71	70	71	70	71
MAYFLY										
Heptageniidae	15	15	21	62	60	40	41	65	91	68
Baetidae	0	1	3	0	0	0	1	0	1	0
Leptophlebiidae	0	0	2	3	0	1	1	1	0	0
Ephemeridae	0	10	0	0	19	5	3	5	5	1
Caenidae	0	1	0	0	1	0	6	1	3	1
Oligoneuriidae	0	0	0	0	0	0	0	0	3	0
Unidentified	0	0	0	0	1	0	5	3	0	0
Change (1970 → 71)		+12		+39		-35		+18		-33
CADDISFLY										
Hydropsychidae	123	8	55	2	8	1	4	0	6	0
Limnephilidae	0	14	3	11	8	22	8	19	4	8
Psychomyiidae	0	8	20	13	9	5	7	14	13	28
Leptoceridae	0	7	9	36	5	37	3	56	8	2
Phryganeidae	0	0	0	0	1	0	0	0	0	0
Unidentified	0	0	0	0	0	1	0	0	0	3
Change (1970 → 71)		-86		-25		+35		+67		+10
DRAGONFLY										
Gomphidae	10	7	0	6	10	2	0	0	0	0
Aeshnidae	0	5	18	9	11	13	14	7	2	5
Libellulidae	0	1	0	0	0	0	0	0	1	0
Cordulegastridae	0	0	0	1	0	0	0	2	0	0
Macromiidae	0	0	0	0	0	0	0	0	0	1
Unidentified	0	1	0	0	0	0	0	0	0	0
Change (1970 → 71)		+4		-2		-6		-5		+3

APPENDIX II - Continued

	K1		K2		K3		K4		K5	
	70	71	70	71	70	71	70	71	70	71
STONEFLY										
Pteronarcidae	44	10	36	11	3	4	0	0	0	2
Perlidae	4	0	2	2	0	0	1	0	0	1
Chloroperlidae	20	11	44	1	8	0	0	1	0	0
Peltoperlidae	0	1	0	0	0	0	0	0	0	0
Change (1970 → 71)		-46		-68		-7		±0		+3
DAMSELFLY										
Agriidae	0	2	0	2	2	1	0	0	0	1
Unidentified	0	0	0	0	0	0	0	0	1	0
Change (1970 → 71)		+2		+2		-1		±0		±0
DIPTERA										
Simuliidae	17	6	12	0	0	1	0	0	0	1
Chironomidae	19	103	13	78	68	138	93	277	33	55
Ceratopogonidae	2	5	0	1	13	0	5	1	0	0
Tipulidae	0	0	7	1	0	0	4	0	2	0
Tabanidae	0	1	0	0	0	0	0	1	0	0
Unidentified	0	0	0	0	0	1	0	0	0	0
Change (1970 → 71)		+77		+48		+59		+177		+21
BEETLE										
Corixidae	4	0	2	0	8	0	2	0	4	3
Elmidae	0	3	0	14	1	8	2	2	0	0
Dytiscidae	0	3	0	0	0	3	0	4	0	2
Hydrophilidae	0	1	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	0	0	0	0	3
Unidentified	0	0	0	0	0	0	10	0	10	0
Change (1970 → 71)		+3		+12		+2		-8		-6

APPENDIX II - Continued

	K1		K2		K3		K4		K5	
	70	71	70	71	70	71	70	71	70	71
CRAYFISH										
Astacidae	2	3	4	3	3	5	2	2	0	1
Change (1970 → 71)		+1		-1		+2		±0		+1
CLAM										
Sphaeriidae	6	2	2	3	1	3	4	2	4	0
Unionidae	0	1	0	2	0	3	0	1	0	5
Change (1970 → 71)		-3		+3		+5		-1		+1
SNAIL										
Viviparidae	27	12	22	17	124	15	48	9	64	10
Bulimidae	0	8	3	2	5	2	0	3	0	6
Physidae	0	0	1	0	0	0	0	0	0	0
Change (1970 → 71)		-7		-7		-112		-36		-48
ISOPOD										
Unidentified	1	0	0	0	0	0	0	0	0	0
Change (1970 → 71)		-1		±0		±0		±0		±0
AMPHIPOD										
Talitridae	0	0	1	0	0	0	1	0	0	0
Change (1970 → 71)		±0		-1		±0		-1		±0

APPENDIX II - Continued

	K1		K2		K3		K4		K5	
	70	71	70	71	70	71	70	71	70	71
OLIGOCHAETE										
Tubificidae	1	6	0	0	7	5	1	6	4	0
Lumbriculidae	0	0	1	0	0	0	0	0	0	0
Change (1970 → 71)		+5		-1		-2		+5		-4
NEUROPTERA										
Corydalidae	0	3	3	0	0	1	0	1	1	0
Sialidae	0	0	0	0	1	0	0	0	0	0
Change (1970 → 71)		+3		-3		±0		+1		-1
FLATWORM										
Planaria	0	9	0	6	3	7	0	9	1	0
Change (1970 → 71)		+9		+6		+4		+9		-1
LEECH										
Unidentified	1	4	0	0	1	1	1	0	1	5
Change (1970 → 71)		+3		±0		±0		-1		+4
MITE										
Unidentified	0	1	1	3	1	1	2	1	1	0
Change (1970 → 71)		+1		+2		±0		-1		-1
Total # Organisms per Station	296	273	285	289	382	326	269	493	263	212
Total # "Taxa"	16	33	24	24	27	26	25	25	23	22